Improving awareness of health hazards associated with air pollution in primary school children: design and test of didactic tools

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Abstract

One of the objectives of the MAPEC-Life project is raising children's awareness on air quality and its health effects. To achieve this goal, we designed didactic tools for primary school students, including leaflets with more information for teachers, a cartoon, and three educational videogames. The tools were then tested with 266 children who attended six primary schools in four Italian cities. A control group of 51 children received only explanations from teachers. An improvement in knowledge after using the audiovisual package was demonstrated, with higher efficacy compared with the control group. In addition, the use of videogames was greatly appreciated.

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1. Introduction

Air pollution is a global problem, mainly in urban areas, and a major environmental risk to health, causing acute respiratory infections, cancer, and chronic respiratory and cardiovascular diseases (Pope Arden, & Dockery Douglas, 2006; Shah et al., 2013).

Urban air is a very complex and variable mixture of numerous classes and subclasses of contaminants, containing many different chemical species (WHO, 2014; EEA, 2014). Children are at a higher risk for the health effects of airborne chemicals because they have a high level of physical activity, spend more time outside, and have higher air intake than adults. Recent data (Bonassi, Znaor, Norppa, & Hagmar, 2004; Bonassi et al., 2007; Bonassi, El-Zein, Bolognesi, & Fenech, 2011; Ceretti et al., 2014) suggest that genetic damage that occurs early in life can increase the risk of carcinogenesis in adulthood.

Air pollution is the first most common concern at European level. In the Special Eurobarometer 416 (European Commission, 2014), half or more of the respondents say that they are worried about air pollution (56%).

Despite the wide efforts that have been made to create awareness of environmental issues, numerous studies have demonstrated a gap between environmental knowledge and awareness and pro-environmental behavior (e.g., minimizing resource and energy consumption, using non-toxic substances, and reducing waste production) (Kollmuss, & Agyeman, 2012). Nevertheless, raising awareness generally drives positive attitudes and eventually positive behaviors, even if many other factors can be associated with them.

Children and young people are often involved in school programs that face environmental problems, and some studies have demonstrated the potential power and effectiveness of school students as catalysts and agents of community attitudes and behavioral change (Ballantyne, Fien, & Packer, 2001; Vaughan, Gack, Solorazano, & Ray, 2003). Even young children can influence everyday household practices, such as walking or riding a bike to school, taking shorter showers, turning off water taps and lights, and purchasing environmentally friendly cleaning products.

To study early biological effects that are caused by exposure to air pollution in children, the MAPEC-Life project (LIFE12 ENV/IT/000614, 2014) has been funded by the European Union. Its goal is to evaluate associations between the concentration of urban air pollutants and biomarkers of early biological effects in children aged 6-8 years. The sampling of air and mucosal cells in children has been performed in elementary schools in five Italian cities (Brescia, Turin, Pisa, Perugia, and Lecce) that are characterized by different levels of airborne particulate matter. The MAPEC study design has been fully described previously (Feretti et al., 2014).

In addition to the scientific objective of the study, the project has provided an opportunity to enter classrooms to explain to children, their parents, and teachers the aims and methods of the research, as specifically requested by school authorities. This creates an ideal context to provide a wider learning experience with regard to the themes of air pollution, health effects, and related healthy lifestyles.

In the present study, we report the experience of the MAPEC-Life Project in designing and validating didactic tools on air pollution, health effects, and healthy lifestyles to be used for children in primary school. We discuss the results that were obtained with the application of didactic tools in six primary schools in four Italian cities (Pisa, Turin, Brescia, and Lecce).

2. Methods

A flow-chart of the design, creation, and testing of the tools is shown in Figure 1.

Figure 1

2.1 *Choice of tools and key messages*

The types of tools to be used in the educational package were discussed in a focus group (Masadeh, 2012), consisting of six teachers in primary schools in Pisa and three researchers of the project. Considering the age of the children, the decision was made that audiovisual aids and games would be preferred by the pupils. Another determination was made that these tools should be complemented by explanations by the teachers. To achieve this aim, specific didactic leaflets that targeted adults (i.e., teachers and parents) were also prepared.

The focus group also discussed topics related to the tools and decided that they should contain five groups of information: air pollution, health effects, cellular effects, policies against pollution, and healthy lifestyles. On this basis, five educational leaflets that specifically addressed teachers and other adults were designed, and a cartoon and three videogames that stressed the key messages were designed for children.

2.2 *Videogame programming*

Flash technology was used to develop the MAPEC games, choosing a solution that has been applied in many animation games, such as 'Farmville' and 'Candy Crush Saga,' which, among other things, allows integration with social networking platforms (Rosenzweig, 2008).

2.3 *Tests of readability and usability of the leaflets for teachers*

The readability of the leaflets was evaluated with the GULPEASE Index (Lucisano & Piemontese, 1988), calibrated to the Italian language and based on two variables: word length and sentence length relative to the number of characters in the text. The leaflets were then tested for usability with six teachers of primary schools who were asked to evaluate their understandability for adults, usefulness, adequacy for teaching purposes, and the difficulty of their topics for children. After evaluation, the teachers suggested some amendments.

2.4 *User tests of videogames*

A preliminary evaluation of the videogames was performed with 10 children and their parents in Pisa. The parents were asked to evaluate the videogames with regard to their

usefulness, understandability, easiness, child involvement, and education efficacy. The time spent playing the games was also recorded. After this initial evaluation of the videogames, the children were asked to judge their enjoyability and usefulness.

2.5 *Pilot study*

Two hundred sixty-six children who attended the second and third grades of seven primary schools in four Italian cities (Pisa, Brescia, Torino, and Lecce) were involved in the pilot study. In the classrooms, the duration of the activity was approximately 2 hours. The test procedure was structured into six consecutive steps:

Table 1..

2.6 *Control test*

A control test was performed with students (n = 51) in the second grade in two primary schools in Pisa. The main objective was to evaluate the influence of the videogames and storyboard on learning the topics covered. The procedure was the same as the one used in the pilot study but without using interactive media or audiovisual aids. The control test procedure was structured according to steps 1, 2, and 5 of the pilot test.

2.7 *Data analysis*

2.7.1 Questionnaire on knowledge

Fisher's exact test ($p < 0.05$) and odds ratios were used to compare the percentages of correct answers for each question before and after the teaching activity in both the pilot group and control group. To assess each child's knowledge, for each question a score of 1 was assigned for correct answers, and 0 was assigned for incorrect or incomplete

answers. The total score for each child was then calculated as the sum of scores for all of the questions.

An independent-samples t-test, with statistical significance set at $p < 0.05$, was conducted to compare the mean scores (pre- and post-questionnaire) in the various groups to assess the effectiveness of the educational package in increasing knowledge by also considering the age of the children.

2.7.2 Questionnaire on perception

For the two questions about the game's enjoyability and usefulness, the answers were expressed as a score from 1 to 4 on a Likert scale (Bernstein, 2005): 1 = not at all, 2 = little, 3 = enough, and 4 = very much. These scores were then analyzed with an independent-samples t-test, with statistical significance set at $p < 0.05$, to evaluate differences between the various school grades. For questions regarding negative impressions about the videogames, the percentages of the number of negative answers were calculated. The open-ended responses were grouped into categories according to their content to calculate the percentage for each category.

3. Results

3.1 *Designed tools*

According to the focus group evaluation, the five most important topics were selected to design the teachers' leaflets:

1) Source and characteristics of the most important air pollutants: NO_x, SO_x, CO, O_3, volatile organic compounds, particulate matter, and polycyclic aromatic hydrocarbons.

2) Effects of air pollution on health. This leaflet described, in simple terms, the effects of pollutants on the respiratory system and other organs, in addition to defense mechanisms against air pollution.

3) Policies to reduce exposure to air pollution: smoking ban, creation of recreational areas for children away from sources of pollution, prohibition against increasing the temperature above 20°C in buildings that are used as residences and public areas, bike sharing, car sharing, carpooling, park and ride, waste recycling, and energy savings.

4) Lifestyles, particularly good and proper nutrition, such as the importance of having breakfast, the quality and variety of food, and the need for physical activity. The negative effects of exposure to secondhand smoke, alcohol abuse, and caffeine consumption were also described.

5) Basic information about the effects of air pollutants at the cellular level. Although explaining the concept of genetic material to primary school students is difficult, very simple information was provided to foster their understanding of the genotoxic and mutagenic effects on DNA.

The main information (outdoor and indoor air pollutants and how to avoid them) was presented on a storyboard that lasted 2.49 minutes before the games (Figure 2).

Figure 2.

For the games, three key messages were chosen:

- Air pollution and health hazards
- Healthy lifestyles
- Effects of pollutants at the cellular level and positive action of vitamins (e.g., fruits and vegetables)

Following the key messages, three games were designed (Figure 3) and embedded in a framework that included teaching leaflets and the storyboard. To increase the children's participation, they could choose either a boy (Vito) or girl (Mina) as a player.

The first game 'CORRI, RACCOGLI GLI ALBERI, EVITA LO SMOG!' (Run, collect the trees, avoid the smog!) was developed at multiple levels. The first level was set in the city (i.e., in a polluted environment). As the game goes on, environmental pollution is reduced. To overcome the levels of pollution, the protagonist must collect trees and avoid clouds of pollution while blasting the avatar when needed. The collection of trees increase the user's score.

The second game 'RACCOGLI LE COSE CHE FANNO BENE!' (Collect things that are good for you!) is characterized by positive elements for health, such as fruits, vegetables, and sports, that fall from above, alternating with harmful elements, such as cigarettes and junk food. The child with his avatar, within 60 seconds, must collect the positive elements to increase the score and avoid collecting the negative elements that reduce the score and block the game for 5 seconds.

Finally, the setting of the third game 'DIFENDI LE CELLULE DAGLI INQUINANTI!' (Defend cells from pollutants!) is inside the human body. The cell protagonist must eliminate free radicals, represented as 'monsters,' using a gun with a limited number of bullets. Along the way, the cell can recharge bullets by collecting vitamins, which increases the number of bullets and the number of lives that the cell has available.

Figure 3.

3.2 *Tests of readability and usability of the leaflets for teachers*

The leaflets were judged as understandable, easy, and adequate by all six teachers who were involved in the development process. Moreover, they were also considered useful or very useful. The complexity of topics was defined as low or medium for lifestyles and environmental policies and medium or high for source and nature of air pollutants and their effects on health, even at the cellular level. The teachers provided some suggestions to simplify the most complex leaflets

The final version of the texts, evaluated by the GULPEASE Index, had a readability value between 41 and 43, which indicates that they were appropriately understood by people with a secondary school education, such as teachers.

3.3 *User tests on videogames*

The results of the usability questionnaires showed that all of the parents found the videogames to be useful, understandable, simple, fun, and educational for children. The average time spent playing the videogames was 12.5 minutes. The children who were interviewed with questionnaires indicated that they liked the videogames, and nearly 60% said they learned something new after playing them.

3.4 *Pilot test results*

3.4.1 Questionnaires on knowledge

Two hundred sixty-six elementary school students who were involved in the pilot study presented significant learning improvements by participating in the videogame-based learning activity, including the leaflets and storyboard. Comparisons of individual responses according to Fisher's exact test indicated a statistically significant increase in knowledge ($p < 0.05$) based on the questions presented in Table 2. In the control group, only one response showed a significant increase ($p = 0.03$).

Table 2.

Considering the differences between total scores before and after the educational activities (Figure 4), a statistically significant increase was observed in the pilot study. The mean score in the post-knowledge test (11.01 ± 0.1186 [M ± SEM]) was higher than the mean score in the pre-knowledge test (9.199 ± 0.1347), and this difference was statistically significant ($t521 = 10.08$, $p < 0.0001$).

The increase in knowledge for second graders ($t367 = 10.38$, $p < 0.0001$) was higher than for third graders ($t140 = 2.504$, $p = 0.0134$). Before the learning activity, the scores of the second graders were lower ($t188 = 5.438$, $p < 0.0001$), but after using the educational package, no significant differences were found between these two groups ($t264 = 0.3912$, $p = 0.6959$).

In the control group, in which the videogames and storyboard were not used, a significant difference in scores ($t100 = 2.471$, $p = 0.0152$) was found before and after explanation of the leaflets. In the pilot study with second graders, the difference in the average scores before and after the educational activity was greater compared with the control group (2.223 vs. 0.96, respectively), demonstrating greater effectiveness of using the entire educational package.

Figure 4.

3.4.2 Questionnaires on perception

Almost all of the children expressed a high level of enjoyability for the videogames (3.85 ± 0.48 [M ± SD]). Two hundred fifty-nine children (97.4%) declared that they

enjoyed them, of which 23 (8.6%) expressed a partially positive opinion and 236 (88.8%) expressed a totally positive opinion. The mean score for third graders (3.947 ± 0.02612 [M ± SEM]) was higher than the mean score for second graders (3.812 ± 0.03901), and this difference was statistically significant ($t262 = 2.879$, $p = 0.0043$). Only seven children (2.6%) expressed a negative opinion, of which four (1.5%) expressed a partially negative opinion and three (1.1%) expressed a totally negative opinion. A total of 66 children (24.8%) indicated some negative perception about the videogames. Table 3 shows these responses, both as a total and according to grade.

Table 3.

The usefulness of the videogame to promote new knowledge was evaluated positively by 249 children (93.6%), with an average score of 3.63 (SD = 0.66). No statistically significant differences were found between grades. One hundred ninety-three children (72.5%) expressed a totally positive opinion; 56 (21.0%) expressed a partially positive opinion; 12 (4.5%) expressed a partially negative opinion; and five expressed a totally negative opinion (1.9%).

For the open-ended question, the comments of 169 children (63.5%) about what they learned were grouped into five categories. Some comments were included in more than one category. Table 4 shows the percentages of children, both as a whole and divided by grade, who expressed different opinions.

Table 4.

4. Discussion

The main purpose of the present work was to create and validate an educational package to promote learning about issues related to air quality in primary school students (7-8 years of age). The tools were designed based on the suggestions of a focus group of six teachers of primary schools and three researchers who are involved in the MAPEC-Life project. Interactions between the teachers, who are in close contact with children and thus able to recognize their training needs, and researchers, who devised the educational package, have been considered key to success of the project.

Furthermore, the package was tested for usability in a small group of children of the same age. Usability testing is widely applied to indicate possible problems in the use of a tool that may hamper its effectiveness and efficiency (Chen, Siew, Kee, & Chee, 2013). Moreover, children are recognized as useful and active participants in the design of interactive systems that are aimed at their age group (Markopoulos & Bekker, 2003).

In the present study, which was performed in the schools at the same time as biological sampling, the participation of the classes in the didactic activities was voluntary. We obtained a convenience sample of children without randomization. For the same reason the control group was limited to 51 children (two classrooms).

The results of the experimental application of the educational tools confirmed the usefulness of audiovisual aids and videogames to promote learning. A significant increase in knowledge was observed on the whole and for the majority of the key messages that were conveyed by the materials. This increase was higher for second grade children because their starting level (i.e., pre-knowledge) was lower. After the experiment, their knowledge reached the same level as older pupils. The educational tools presented the greatest usefulness and efficacy for second graders, indicating that this grade level is the preferred target.

Although the control group was small, it demonstrated the lower efficacy of the teaching activity when it lacked audiovisual aids, thus strengthening evidence of the usefulness of the comprehensive design package.

The usefulness of a game-based learning approach has been demonstrated in many studies (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Warren, Dondlinger, & Barab, 2008; Papastergiou, 2009; Tüzün, Yılmaz-Soylu, Karakus, İnal, & Kızılkaya, 2009). Play, in its diverse forms, constitutes an important part of children's cognitive and social development. Over the last 30 years, computer games have increasingly replaced more traditional games as leisure activities. A new generation of students, termed 'digital natives' or the 'Net generation,' is entering the educational system. In view of this generational change, the use of traditional teaching approaches appears to be insufficient, and the use of information technology tools may increase student motivation. Considering the age of the children who are involved in the MAPEC-Life project (i.e., in their first 3 years of primary school), audiovisual tools and particularly videogames have been recognized as being very efficient for motivating children to actively participate in learning activities (Yien, Hung, Hwang, & Lin, 2011; Banos, Cebolla, Oliver, Alcañiz, & Botella, 2012).

Different types of audiovisual aids that convey issues related to air pollution have been produced by various institutions, such as the United States Environmental Protection Agency (USEPA, 2015). However, few studies have quantitatively assessed the effectiveness of such tools (Bennett, Maton, & Kervin, 2008). In the present study, the creation and use of educational tools was accompanied by evaluations of their efficacy and acceptability.

Our results confirmed prior evidence of the beneficial effects of computer games as instructional tools (Kulik, 1994), indicating that they strengthen and support the

motivation to learn because they are attractive to students, present a challenge, elicit curiosity, and allow individual students to control what is happening in the game (Jenkins, 2002).

In the field of environmental and health education, positive behaviors should be induced in children as early as possible, and school is considered one of most important settings to implement health promotion programs (WHO, 1998; Teutsch, Gugglberger, & Dür, 2015).

The education of children has been shown to positively influence the behaviors of adults (e.g., issues related to waste collection or indoor smoking) (Ballantyne et al., 2001; Vaughan et al., 2003, Damerell, Howe, & Milner-Gulland, 2013). The efficacy of teaching is strongly influenced by the student's interest. The MAPEC-Life project studies the early effects of air quality on children at the cellular level and has stimulated children's curiosity about air pollution and its effects.

The teaching efficacy of the audiovisual tools that were developed herein was reflected by their ratings of enjoyability that were declared by the majority of the students. Higher motivation, attention, and concentration have been related (Rosas et al., 2003) to the perception that an activity is 'fun' (i.e., visually and cognitively attractive to children). According to several authors (Malone, 1981; Turkle, 1984; Hubbard, 1991), the criterion of attractiveness must prevail when designing educational software, with high speed, an adequate level of complexity, clear goals, independence from physical laws, and wielding power. Unfortunately, educational games that are commonly presented in institutional contexts are designed more according to informational content than to playing efficiency. Moreover, they are often evaluated not in terms of efficacy or enjoyability (Connolly, Boyle, MacArthur, Haineya, & Boyle, 2012).

The importance of teachers in the educational process should be emphasized. Audiovisual tools must be considered only as aids in classroom activities that are always directed by teachers. For this reason, educational packages should be accompanied by a wider explanation and user instructions for teachers, and teachers should also be deeply involved in designing and evaluating the material. In our experience, the contribution of teachers is essential for developing and implementing tools and facilitating their acceptance and performance in classroom activities.

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Conflict of interest statement

None declared.

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Table 1. Phases of the pilot study

Phase	Content
1. Pre-knowledge test	Students were given a short test (13 multiple-choice questions) to assess their prior knowledge about the learning topic.
2. Teaching leaflets	Academic researchers, supported by teachers, presented the key concepts of the leaflets to students.
3. Storyboard cartoon	An introductory video (lasting 2.49 minutes) was shown to illustrate the main educational content of the games to the children.
4. Educational games	Children, using an electronic whiteboard, could play the videogames. Every child played at least one game and could see fellow children playing the games.
5. Post-knowledge test	After playing the games, the students were asked to again complete the pre-knowledge test.
6. Game questionnaire	To assess perceptions of the tools, the children were asked whether they liked the game in terms of enjoyability and utility using a Likert scale. In cases in which the children responded that the game was unpleasant, they were asked about the reasons for this. Finally, an open-ended question allowed children to write what they learned.

Table 2. Increase (%) of correct answers after the education intervention and significativity of differences (Fisher's exact test p value and odds ratio) for each question.

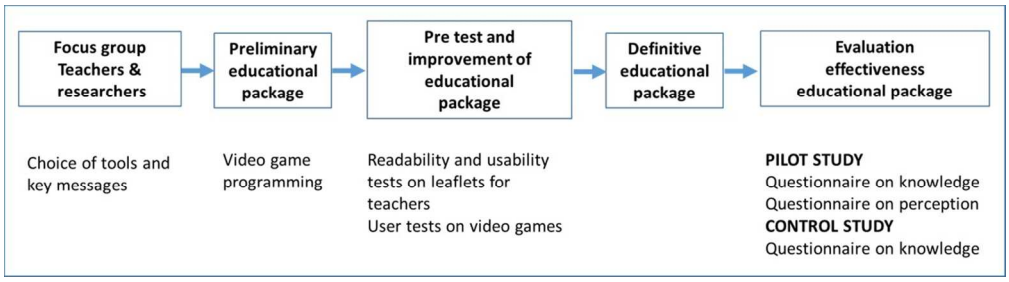
QUESTION	PILOT STUDY			CONTROL STUDY		
1 - What behaviors are correct to combat the health effects of air pollution?	**%**	***p* value**	**Odds ratio**	**%**	***p* value**	**Odds ratio**
1a - Walking on an urban street	**14.7**	**<0.0001**	**2.98**	-5.88	0.2426	0.134
1b - Going to the park	1.88	0.5865	1.20	13.7	0.1091	2.83
1c - Bicycle riding in the countryside	3.76	0.2891	1.32	1.96	1.0000	1.11
1d - Walking in downtown	5.64	0.1764	1.32	5.88	0.6458	1.38
1e- Eating chips, hamburgers, and donuts	**7.14**	**0.0294**	**1.75**	1.96	1.0000	1.11
1f - Eating oranges	4.13	0.1539	1.57	-1.96	1.0000	0.815
2 - What organ is most affected by air pollution?	**14.3**	**<0.0001**	**5.23**	9.80	0.1599	3.90
3 - What are the health effects of particulate matter?	**19.5**	**<0.0001**	**4.03**	13.7	0.1874	1.98
4 - What are the differences between each type of particulate matter?	5.26	0.2005	1.31	3.92	0.8102	1.26
5 - What is the ideal temperature at home?	**28.2**	**<0.0001**	**3.95**	17.6	0.0566	2.87
6 - What food is highest in vitamin C, which increases the body's defenses?	**6.78**	**0.0109**	**2.29**	1.96	1.0000	1.23
7 - What does passive smoking mean?	**36.1**	**<0.0001**	**4.81**	13.7	0.2343	1.74
8 - What are free radicals?	**33.1**	**<0.0001**	**3.97**	**23.5**	**0.0289**	**2.611**

Table 3. Negative judgments of children about the videogames. Percentages were calculated for the total number of children (n = 266) and each grade (n = 191 for second grade and n = 75 for third grade).

Subject	Total	Second grade	Third grade
Too slow	36 (13.5%)	33 (17.3%)	3 (4.0%)
Too difficult	15 (5.6%)	12 (6.3%)	3 (4.0%)
Boring	10 (3.7%)	9 (4.7%)	1 (1.3%)
Other	6 (2.2%)	4 (2.1%)	2 (2.7%)

Table 4. Categories of responses to open-ended questions about the new concepts learned in the school activities. Percentages were calculated for the total number of children (n = 266) and each grade (n = 191 for second grade and n = 75 for third grade).

Subject	Total	Second grade	Third grade
Smoking and passive smoking	34 (12.8%)	29 (15.2%)	5 (6.7%)
Temperature of a house	6 (2.3%)	1 (0.5%)	5 (6.7%)
Health benefits of fruits and vegetables	54 (20.3%)	44 (23.0%)	10 (13.3%)
Physical activity	10 (3.8%)	8 (4.2%)	2 (2.7%)
Health effects of air pollution	68 (25.6%)	51 (26.7%)	17 (22.7%)
Other	14 (5.3%)	8 (4.2%)	6 (8.0%)



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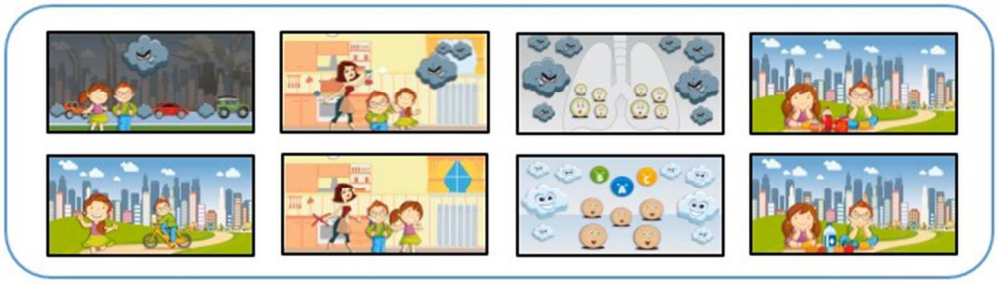

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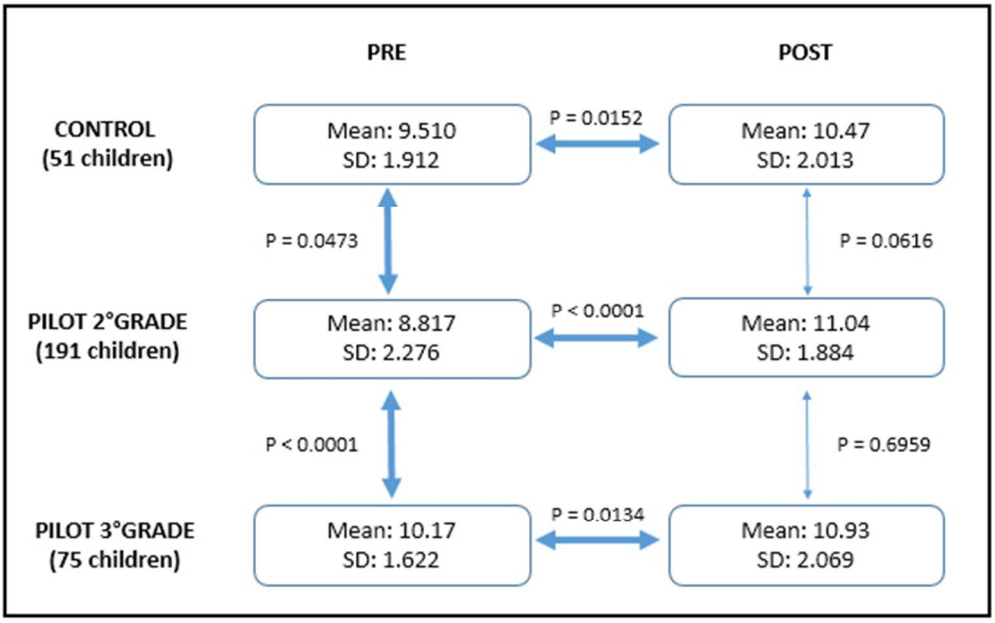

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